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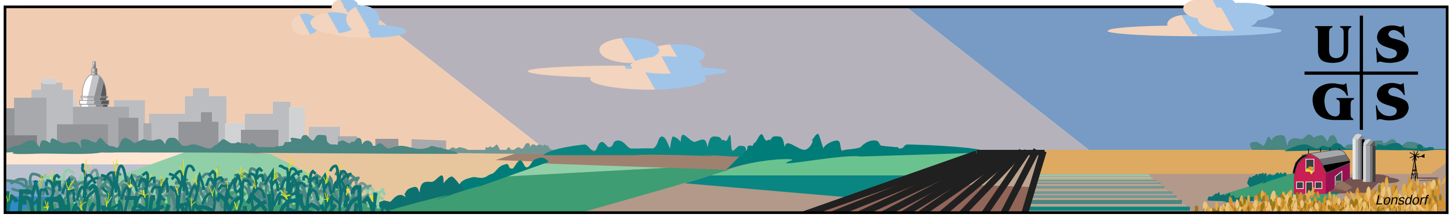



# Evaluating Barnyard Best Management Practices in Wisconsin using Upstream-Downstream Monitoring

by Todd D. Stuntebeck

## Introduction

The Nonpoint Source Water Pollution Abatement Program was created in 1978 by the Wisconsin Legislature. The goal of the program is to improve and protect the water quality of lakes, streams, wetlands, and ground water within selected priority watersheds by controlling sources of nonpoint pollution. For each selected watershed, the Wisconsin Department of Natural Resources drafts a management plan that guides the implementation of pollution-control strategies known as Best Management Practices (BMP's). This plan summarizes resource and land-use inventories, describes the results of pollution-source modeling, and suggests pollution reduction goals. The U.S. Geological Survey, through a cooperative effort with the Wisconsin Department of Natural Resources, is monitoring water-quality improvements that result from the implementation of BMP's. The data collected are then compared to the watershed plans to assess progress and determine whether goals are being realized. This fact sheet describes the data-collection efforts, preliminary results, and planned data-analysis techniques of monitoring projects for pre-BMP conditions at two barnyards, one each on Otter Creek and Halfway Prairie Creek.

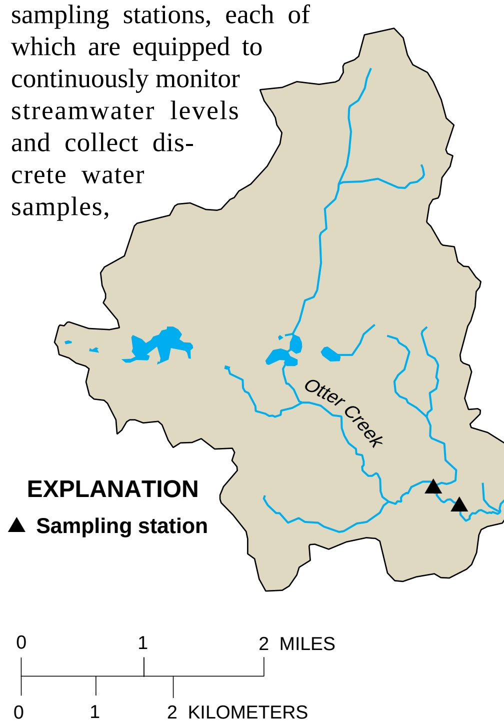
## Data Collection

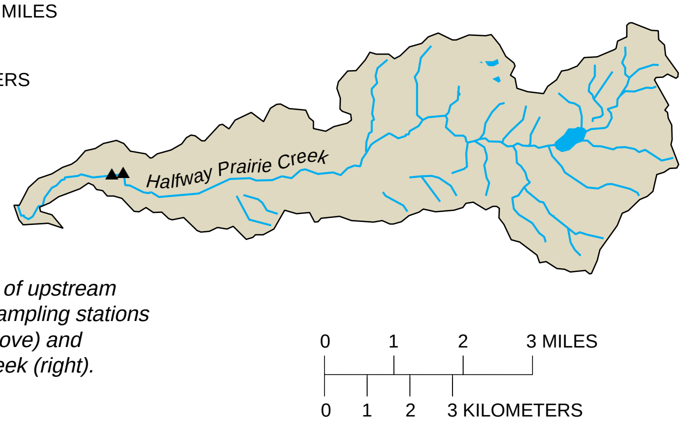
Two sampling stations were established on each stream (fig. 1). One station is upstream from a single barnyard-runoff source and the other station is downstream from that same source. The barnyards investigated were identified by each watershed plan as critical nonpoint sources based on herd size, lot size, proximity to the stream, and downslope overland flow characteristics.

Otter Creek is within the Sheboygan River Priority Watershed, 15 miles west of Lake Michigan, in east-central Wisconsin (fig. 1). The drainage area of Otter Creek is 9.2 square miles at the downstream sampling station, and land use in the watershed is 67 percent agricultural (Bachhuber and Foye, 1993). Upstream and downstream sampling stations, each of which are equipped to continuously monitor streamwater levels and collect discrete water samples, were installed at Otter Creek in March 1994. Water samples are collected with a refrigerated water-quality sampler that is activated by the rise and fall of streamwater levels.

Halfway Prairie Creek is within the Black Earth Creek Priority Watershed, 20 miles northwest of Madison, in south-central Wisconsin (fig. 1). The drainage area of Halfway Prairie Creek is 16.1 square miles at the downstream sampling station, and land use in the watershed is 60 percent agricultural (Eagan and Morton, 1989). Upstream and downstream sampling stations were installed at Halfway Prairie Creek in April 1995. The upstream sampling station continuously monitors streamwater levels and precipitation and collects discrete water samples with a refrigerated water-quality sampler. The downstream station is equipped to collect water samples only.

Upstream-downstream sampling schemes have the inherent potential for upstream loading sources to mask the effects of the investigated source, because individual inputs are often small compared to the cumulative inputs from upstream (Spooner and others, 1985). To reduce the potential for this problem, project investigators added two enhancements to the sampling design used at Otter Creek in order to improve the isolation of



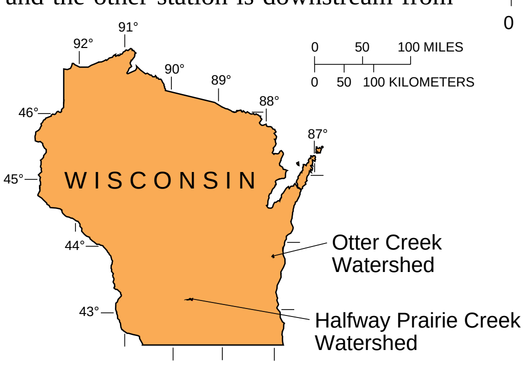




*Figure 1. Location of upstream and downstream sampling stations for Otter Creek (above) and Halfway Prairie Creek (right).*

barnyard runoff at Halfway Prairie Creek. First, the water-quality samplers are activated by precipitation and are programmed to collect time-integrated samples for an initial period. This enhancement will be added to the Otter Creek sampling design for the post-BMP monitoring period. Samples are then collected in response to the rise and fall of streamwater levels in a manner similar to that at the Otter Creek stations.

Two benefits of this approach are that (1) it allows for sampling of barnyard runoff in the receiving stream before streamwater level increases can be sensed, thereby effectively isolating the barnyard runoff from nonpoint-pollution sources upstream, and (2) it allows sampling during small storms in which local inputs from the barnyard are apparent, but little storm runoff from the upstream areas of the watershed is observed. A second enhancement to the Otter Creek sampling design is that the upstream and downstream stations at Halfway Prairie Creek are located close enough together to allow a direct electronic connection and, hence, the collection of concurrent samples from both water-quality samplers. This design allows for statistical comparisons between concurrent individual upstream and downstream concentrations in water samples.

Samples of streamflow were collected during 10 storms between April 1994 and June 1995 at Otter Creek, and 10 storms during April-June 1995 at Halfway Prairie Creek. Samples were analyzed for total phosphorus, ammonia nitrogen, biochemical oxygen demand (BOD), suspended solids, and fecal coliform bacteria. All are known to be potential indicators of nonpoint pollution from barnyards.

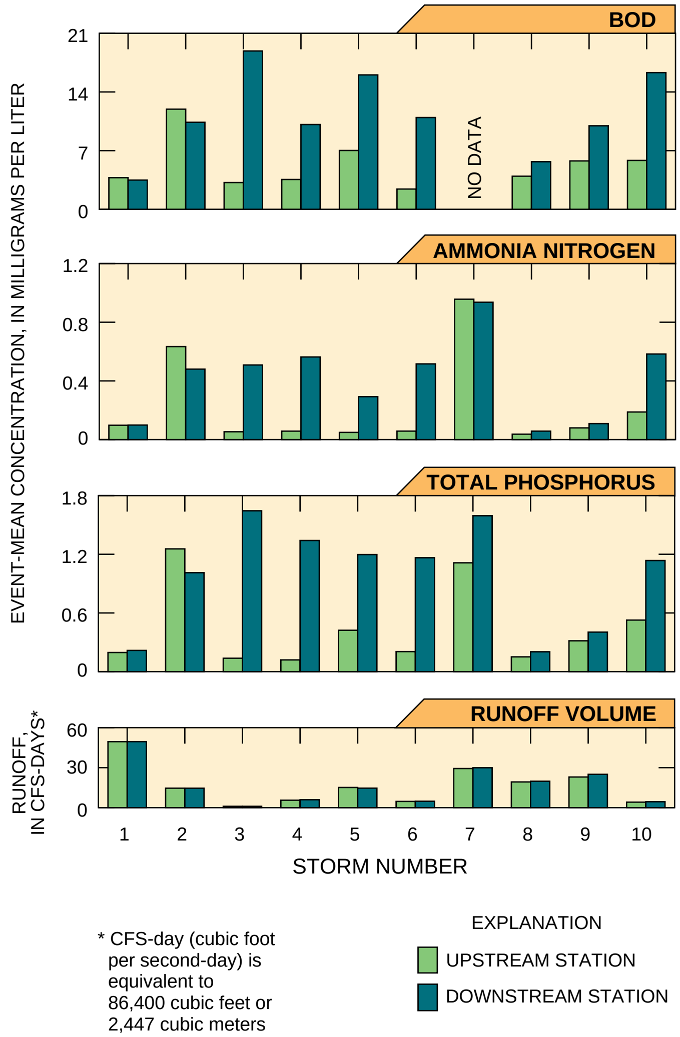



*Figure 2. Event-mean concentrations and runoff volume for selected storms, Otter Creek, Wisconsin.*

▲ *Barnyard-runoff study site at Otter Creek.*

**Data collected before implementation of BMP's indicate that at each site, average downstream event-mean concentrations of total phosphorus, ammonia nitrogen, and BOD were significantly greater than average upstream event-mean concentrations.**

## Results

The continuous streamflow and instantaneous water-quality data were used to estimate mass transport (load) during individual storms. Loads were computed for total phosphorus, ammonia nitrogen, and BOD by summing the product of instantaneous concentration and streamflow for each period of storm runoff (Porterfield, 1972). Runoff volumes were computed by summing the streamflow rate for each period of storm runoff. Event-mean concentrations were computed by dividing the load by the runoff volume.

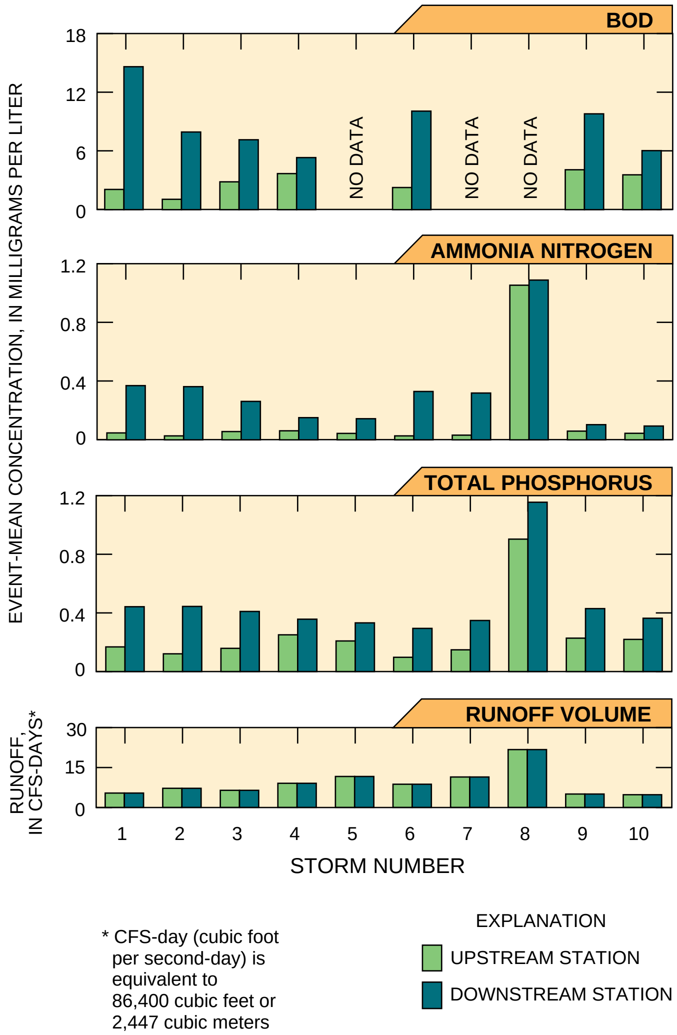



*Figure 3. Event-mean concentrations and runoff volume for selected storms, Halfway Prairie Creek, Wisconsin.*

**Concurrent upstream and downstream samples collected early in periods of storm runoff will likely allow improved detection of differences in concentrations, even for large storms.**

In general, event-mean concentrations of total phosphorus, ammonia nitrogen, and BOD were greater at the downstream station than at the upstream station for most periods of storm runoff at Otter Creek (fig. 2). Using a paired Student's t-test, it was determined that for each constituent, the average of the differences between upstream and downstream event-mean concentrations was significantly different from zero at the 95-percent confidence level. In other words, average downstream event-mean concentrations of total phosphorus, ammonia nitrogen, and BOD were significantly greater than average upstream event-mean concentrations. The statistically significant increases in event-mean concentrations downstream from the barnyard suggest that the investigated barnyard-runoff source is an important contributor to the concentrations of total phosphorus, ammonia nitrogen, and BOD in Otter Creek for the storms monitored.

Upstream and downstream event-mean concentrations of total phosphorus, ammonia nitrogen, and BOD during storms 1 and 2 did not follow the same general trends observed during the other eight storms. The most likely reason for this observation is that the threshold for initiation of sampling was set too high for the first two storms. Based on this experience, it was realized that the threshold could be set lower. If sampling is initiated sooner, the downstream site is more likely to capture the higher pollutant concentrations expected in the early part of the barnyard runoff.

Event-mean concentrations of total phosphorus, ammonia nitrogen, and BOD downstream from the barnyard on Halfway Prairie Creek were also generally higher than those upstream (fig. 3). Average downstream event-mean concentrations of total phosphorus, ammonia nitrogen, and BOD were significantly greater than average upstream event-mean concentrations at the 95-percent confidence level. Differences between upstream and downstream event-mean concentrations at Halfway Prairie Creek were less variable than those at Otter Creek. Time-integrated samples collected early in the storms at Halfway Prairie Creek may have helped to isolate barnyard runoff from other upstream sources of pollution loads. Similar runoff volumes among the

▲ *Barnyard-runoff study site at Halfway Prairie Creek.*

**The pollutant reductions expected from the BMP's at each site are greater than the changes needed to observe a statistically significant improvement in water quality.**

storms and minimal seasonal changes between storms also may explain this lower variability.

The difficulty in finding differences between upstream and downstream event-mean concentrations during large periods of storm runoff is apparent for storm 8 at Halfway Prairie Creek. Because concurrent samples were collected, however, individual concentration comparisons may highlight changes between the upstream and downstream differences over time. Such comparisons would likely focus on the beginning of the storms, when most of the runoff is local and from the barnyard source. Although discrete comparisons have not yet been conducted, the statistically significant increases in event-mean concentrations downstream from the barnyard suggests that the investigated barnyard-runoff source is an important contributor to the concentrations of total phosphorus, ammonia nitrogen, and BOD in Halfway Prairie Creek for the storms monitored.

## Planned Data Analysis

Upon completion of monitoring during the post-BMP period, the U.S. Geological Survey and the Wisconsin Department of Natural Resources will determine whether the barnyard-runoff controls have improved the water quality in these streams. The event-mean concentration data will be analyzed in a manner similar to that described by Spooner and others (1985) to test for upstream and downstream differences. These differences will be computed for pre- and post-BMP storms, resulting in two independent data sets. These two data sets will then be compared to determine whether a statistically significant decrease in the average of the differences has occurred. Analysis of the pre-BMP data revealed that average downstream event-mean concentrations exceeded average upstream event-mean concentrations before BMP's were implemented. If, after implementation, the management practice has reduced the downstream concentrations, a corresponding decrease in the average difference between upstream and downstream event-mean concentrations for the post-BMP period would be expected.

Using the Student's t-test to find differences between two independent data sets, one can develop an equation to estimate the minimum amount of decrease in post-BMP downstream event-mean concentrations necessary to be considered statistically significant. This "minimum detectable change" is usually expressed as a percentage. If the pre- and post-BMP sample sizes are assumed to be equal (10 storms) and the variance in the differences between upstream and downstream concentrations is kept constant, minimum detectable changes for significance at the 95-percent confidence level are the following:

| | MINIMUM DETECTABLE CHANGE | | |
|---|---|---|---|
| Creek | Total Phosphorus | Ammonia Nitrogen | BOD |
| Otter | 50 | 50 | 40 |
| Halfway Prairie | 10 | 30 | 40 |

To clarify, the average downstream post-BMP event-mean concentrations of total phosphorus at Otter Creek would have decrease by at least 50 percent for the change to be considered statistically significant at the 95-percent confidence level. These values are conservatively high because variance in the downstream-upstream differences for average pre- and post-BMP event-mean concentrations was assumed to remain constant. One would expect the actual variance to decrease after BMP implementation, thus decreasing the minimum detectable changes. As discussed earlier, the differences in event-mean concentrations between upstream and downstream samples for Halfway Prairie Creek were less variable than those for Otter Creek. This is reflected in lower minimum detectable changes. According to the watershed plans (Bachhuber and Foye, 1993; Eagan and Morton, 1989), the minimum detectable changes are smaller than the pollutant reductions expected from BMP implementation at each site.

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